Multicolor electrophotometry of the peculiar object V1357 Cyg=Cyg X-1 in the period 1986 – 1992.

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This paper is dedicated to Tatyana Musatova, who remain continuing sources of inspiration

Abstract Observations of close binary system (CBS) V1357 Cyg=Cyg X-1 in the $WBVR$ bands are reported. Photometry was carried out at the telescopes located in Kazakhstan, Uzbekistan and Crimea equipped with single-channel $WBVR$-photometer with photon counting. 1358 individual observations in $WBVR$ bands on 202 nights were obtained.

The analysis of the photometric data allows to conclude that different photometric effects are superimposed on the orbital light curve of the system. Among them are brightness declines, outbursts with different duration and amplitude, chaotic variability, which sometimes exceeded the ellipsoidal variability. Strong brightness decreases with magnitude $0^m.035 - 0^m.045$ are observed, they are equal to the contribution of accretion disc to the total luminosity of the system.

10 years of photometric monitoring allowed to detect continous brightening of the system, followed by luminosity decline (slow outburst). After the maximum in 1994-96 the decline was equal to 7% in the W band, 4% in the V band, and 2% in the V and R bands.

This paper continues the series of works on close systems with X-ray sources.

Key words: Close binary systems - luminosity - ellipsoidal variability - accretion disc

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1 INTRODUCTION

Bright double X-ray systems have long series of electrophotometric observations, which allow to determine many main physical parameters of these CBS. But nevertheless many fundamental properties of stellar matter flows in these systems remain unclear.

The spectra of these objects contain nesessary additional information. Taking into account the difficulties in studies of such double systems, precision and detailed spectroscopic observations should be carried out for the astrophysical objects which have already been investigated by other methods.

The specialized new generation X-ray satellites EINSTEIN, ROSAT, GINGA, ASCA, RXTE, CHANDRA, GRANAT, MIR-KVANT, GRO, XXM, and others have systematically studied double systems with neutron stars and black holes.

The close system V1357 Cyg=CygX-1 is the only one CBS which satisfies all these selection criteria: it is one of the brightest X-ray double systems in the optical wavelengths, it is studied in detail by photometric methods, attracts attention of X-ray observatories and is the first candidate for black holes (BH).

The relativistic object Cyg X-1 was discovered in X-rays and later was identified with the optical companion of HDE 226868 with V-band brightness of $\approx 9^m$.

1.1 GENERAL CHARACTERISTICS OF THE DOUBLE SYSTEM AND THE TASKS OF INVESTIGATION

Up to now this system remains No.1 black hole candidate, because the mass of the relativistic component in this CBS exceeds $7M_\odot$ [1].

Recently investigations in different spectral bands resulted in discovery of new fine photometric effects for Cyg X-1. For example, besides orbital variability with period of $5^d.6$ different kinds of outbursts were revealed, and the so-called precession period of $147^d/294^d$ was discovered.

Significant correlation between the long-period variations of optical and X-ray (2 – 10 keV) radiation is observed, typically with time delay of one or two weeks.

According to generally accepted model the CBS consists of the optical star – supergiant of spectral class O9.7Ia,b ($V = 8^m.8$) and the relativistic object, which is surrounded by an accretion disc (AD), radiating mainly in X-rays: $L_x = (3.3 - 5.5) \cdot 10^{37}$ erg/s [2]. The distance to the object is $\sim 2,5$ kpc. The temperature of the supergiant can be estimated as 25000 K [3], 29500 K [4], [5] and up to 32000 K [6].

The contribution of AD to the total luminosity of the system is only 4% in the V band [3]; [7].

Cyg X-1 system has fast (about milliseconds) non-periodic variability of X-ray radiation [8], which is one of the important properties of matter accretion on the black hole [9]; [10].

The classical effect of regular variability is observed for Cyg X-1 system: the ellipsoidal effect, which results from tidal deformation of the shape of the optical star, which has deterministic character for such CBS.

The inclination, i, remains relatively uncertain. On the basis of analysis of absorption lines, [51] estimated $i = 33° \pm 5°$.

On the other hand, the polarimetric measurements of [53] yield $25° - 67°$. In our study, we consider the inclination range of $30° - 60°$.

We assume the black hole and the primary masses of 20 and $40 M_{\odot}$ [55], respectively, and a circular orbit.

The radius of the primary is taken as $r_{\star} = 1.58 \times 10^{12} cm$ ([54]).

The , and the orbital velocities are .

THE MAIN TASKS OF THIS WORK ARE:

- to obtain homogeneous observational data in the W, B, V, R bands;
- to obtain dense rows of photometric observations every season;
- to obtain observations with high temporal resolution to reveal fast variability and fine photometric effects;
- to obtain observations covering the moments of accretion disc entering the eclipse and exit from eclipse.
- to investigate the behaviour of the system at "off"and "on"states on the base of photometric data.

1.2 INTRODUCTORY NOTES FOR THE OBSERVATIONS OF THE CLOSE SYSTEM

It is nesessary to remind that at the beginning of 1980-ies analysis of X-ray observations of the system at 30 keV band [11] revealed the periodicity with characteristic time of $\sim 300^d$.

Sometimes later [12] discovered long-time variability of the system with period 294^d in the passband 3-6 keV using uniform observations from X-ray satellite Vela. Later [13] has shown the existence of this periodicity in optical wavelengths and concluded that the shape of the optical light curve is different at various phases of the 294^d-long precession period.

The orbital light curve during outburst differs from the average annual light curve by extra extinction of radiation at orbital phases $\varphi = 0.00 - 0.50$, this effect can last about 40 days after the end of outburst, as it happened, for example, in 1980 [14]; [7].

2 OBSERVATIONS OF THE CLOSE SYSTEM

Photoelectric observations of V1357 Cyg=Cyg X-1 were carried out in the $WBVR$ system. Total number of observations is 1358 individual estimates on 202 nights in the period 1986 – 1992.

The observations were carried out at the reflectors Zeiss-600, Zeiss-1000 and AZT-14 with the same equipment: single-channell photometer with $WBVR$ filters and FEU-79 photomultiplier (multialkali photocathode S-20).

For each season the coefficients of transformation of instrumental photometric system were determined.

The photometric observations are presented in Table 1. Reduction was carried out with differential method. Sometimes the extinction coefficients were measured by Nikonov's method, usually during the best photometric nights. Then the mean coefficients ξ were calculated for each season of observations, and for each night the zero-points η were computed using the mean values of ξ. Mean values of ξ and their errors are presented in Table 2, where n is the number of nights used for calculation.

Table 1 with photometric data looks this way:

Таблица 1: Results of observations

№ No/Nb	JD2400000+.	φ	W	B	V	R	n
1	46615.3830	0.873	15.075	15.125	14.667	14.328	06
2	46616.4574	0.983	15.144	15.314	14.946	14.660	08
3	46618.4099	0.181	14.855	15.306	14.779	14.585	06
4	....	....	......	......	......	......	..

where n is the number of individual observations in a night.

Table 2 with extincion and transformation coefficients is reported in the Database.

Таблица 2: Transformation coefficients

1. Season of observations: July - September 1986, 1987, 1988. Reflector: AZT-14 (400 mm) Tjan-Shan observatory	2. Season of observations: August - October 1986, 1987, 1988, 1989, 1990, 1992. Reflector: Zeiss-600 Crimean Observatory SAI;	3. Season of observations: July - September 1986, 1987, 1988, 1990, 1992, 1994. Reflector: Zeiss-600 Maidanak Observatory SAI;
$\xi_V = 0.054 \pm 0.002$ $\xi_{W-B} = 0.997 \pm 0.009$ $\xi_{B-V} = 0.929 \pm 0.005$ $\xi_{V-R} = 1.068 \pm 0.008$ $n = 27$	$\xi_V = 0.013 \pm 0.003$; $\xi_{W-B} = 0.962 \pm 0.005$; $\xi_{B-V} = 1.102 \pm 0.003$; $\xi_{V-R} = 1.088 \pm 0.004$; $n = 38$	$\xi_V = 0.012 \pm 0.003$; $\xi_{W-B} = 0.958 \pm 0.004$; $\xi_{B-V} = 0.937 \pm 0.007$; $\xi_{V-R} = 1.065 \pm 0.007$; $n = 41$

ELECTRONIC ADDRESS OF THE DATABASE OF PHOTOMETRIC OBSERVATIONS

The results of observations of CBS V1357 Cyg=Cyg X-1 in the optical wavelengths are presented in Table 1 at the address: http://lnfm1.sai.msu.ru/∼ sazonov/ Cyg X-1

COMPARISON STARS AND THE CONTROL STAR

The observations of the program object were made relative to the comparison stars and the control star from the list presented in Table 3:

Таблица 3: Comparison and control stars

№ no/no	Star	$BD/GCVS$	V	$U-B$	$B-V$	$V-R$
1	c	+34:3812	9.082	-0.013	-0.029	0.024
2	a	+34:3816	-	-	-	-
3	1	+35:3895	6.998	+0.051*	0.040	0.031

Note:*- color $(W-B)$ is reported.

Orbital phases of CBS V1357 Cyg=Cyg X-1 are presented according to the ephemerides by [14], [15]:

Min I hel = JD 2441163.529(±0.009) + 5^d.59985(±0.00012)

The phases of precession periods were computed according to the ephemerides by [16], [17]:

Min I hel = JD 2449953 + 147^d.0·E

Min I hel = JD 2449953 + 294^d.0·E

According to these elements the minimum at the orbital phase φ =0.0 corresponds to location of X-ray source of CBS in front of the optical component (the moment of upper conjunction of the X-ray source), and the mimimum at the orbital phase φ =0.5 occurs when the X-ray source is behind the normal star.

The observations in the period 1986–1987 were carried out relative to the standard star BD+34:3816, which was later replaced by BD+34:3812, because BD+34:3816 was suspected to be variable with small amplitude [18], [19]. Later [20] confirmed that star BD+34:3816 is a variable with small amplitude (∼ 0^m.01) and periodical components in the light curve. The result was based on special photometric investigation.

The star BD+35:3895 was used as control star during these observations.

It is nesessary to stress that in 1988–1992 author used the star BD +34:3812 as local standard because variable V1357 Cyg and BD +34:3812 have comparable brightness. Besides, BD +34:3812 is the star of early spectral class, but it's color is different from V1357 because of strong interstellar extinction. The difference in color results in significant corrections which were applied during reduction.

3 REGULAR VARIABILITY OF BRIGHTNESS OF CLOSE SYSTEM

While analysing the light curves in the period 1986–1999 the strong physical irregular variability of V1357 Cyg attracts special attention. It is superposed on the periodical brightness changes, resulting from ellipsoidality, and depending also on the precession period $147^d/294^d$ (Fig.1-4).

See (Fig.5) B from V, vs. orbital phase φ for the 1989-1999 season.

It is nesessary to note that during the constant increase of amplitude of variability in all four spectral bands every year of observations the irregular brightness fluctuations take place in phase with regular changes, and while decrease of amplitude in antiphase [21].

The author used his 7-year long multicolor $WBVR$ observations to investigate the photometric variability of optical component of CBS. For qualitive analysis of these data the author used also the published optical [22]; [17]; [23]; [7] and X-ray [24]; [25]; [26] data.

The errors of these observations are typically $0^m.003 - 0^m.007$ on different nights.

The figures show that the mean light curve of the system V1357 Cyg=Cyg X-1 is close to sinusoidal, although it is evident that the minimum at phase $\varphi = 0.50$ is slightly wider and shallower than at orbital phase $\varphi = 0.00$.

The orbital phase $\varphi = 0.00$ corresponds to the moment of upper conjunction of X-ray source and the optical component of the system.

This observable difference at the light curves can be interpreted as the evidence that the optical component fills it's Roche lobe, and the star is not ellipsoidal, but pear-shaped. In this case the role of gravitational darkening is increasing.

The observations revealed flares, which result from appearance of temporarily hot regions, so-called "hot spots". The analysis of X-ray emission reveals strong correlation between appearance of "hot spots" and decrease of X-rays ("dips"), the reason is perhaps the emergence of absorbing gas at the light beam of the observer.

The non-stationarity of gas flow through the inner Lagrange point L_1 from the optical component of the system to the accretion disc (AD) of the relativistic object can generate shock waves in the gas which surrounds the system. The shock waves are formed also when gas enters the AD, causing redistribution of scattering and absorbing matter in the vicinity of the relativistic object, and this fact is revealed in the optical radiation.

Different short-term variability is occasionally superposed on the mean orbital light curve of the system, it is not strictly dependant on the orbital and precession phases. The flare variability seems to be integrated to this occasional irregular variability: strong and long outbursts with amplitude up to $\Delta = 0^m.03 - 0^m.04$, and also short-period flares with amplitude of $\Delta = 0^m.01$; long (up to 7–10 days) brightness decreases with amplitude up to $\Delta = 0^m.040 - 0^m.045$; and also chaotic irregular variability.

The mentioned above types of variability, as a rule, coincide with local maxima and minima of X-ray radiation.

This type of variability was detected during studies of photometric changes on the light curve with characterisic times from 2-3 days to 10-12 days (as in the seasons 1986 and 1988; see Fig. 1,3).

All these photometric phenomena are probably due to the activity of X-ray component during Cyg X-1 transition to the "soft"state [24]; [25]; [26]; [14].

Ellipsoidal light curve shows relatively short outbursts with amplitude up to $\Delta = 0^m.020 \pm 0^m.030$ and length of about 3-4 hours during the night of observations. At these observing seasons the symmetry of double wave is absent at orbital phases $\varphi = 0.00$ and $\varphi = 0.50$. This feature of the light curves of the optical component of V1357 Cyg is probably connected to some asymmetry of strong gas flows in the system.

4 FAST VARIABILITY OF THE SYSTEM

Fast variability of the star in $WBVR$ bands was investigated at minimum and maximum brightness on time spans of $\sim$ 60-90 s. The deviations of brightness from the mean value within 3σ on time intervals of 60-90 s were detected. The amplitude of fast variability is up to $0^m.005 \div 0^m.007$. Such fast variability is probably characteristic of short-time outbursts in the system.

Analysis of fast variability and functional dependence between optical and X-ray bands revealed very low dependence at the level of a few percent.

5 ANALYSIS OF THE CHANGE OF THE MEAN LEVEL OF BRIGHTNESS OF THE SYSTEM

Qualituve comparison with the observations of 1986 – 1998 allows to conclude that long-term small-amplitude "outburst"took place at the system. This long-term variability is probably connected to the evolutionary changes of supergiant in the close system. This is confirmed by the change of color indices at there epochs. Consecutive spectral observations revealed the cooling of supergiant by about 2000 K by comparison to the "peak temperature"of 1995 – 1996. The spectral type of the supergiant also changed. The color excess also slightly decreased compared to the previous value of $E(B - V) = 1.12$ [37].

The annual changes of the mean brightness of close system V1357 Cyg=HDE 226868=Cyg X-1 for the period 1986 – 1998 are presented below.

Таблица 4: The data on annual changes of the mean brightness of V1357 Cyg=Cyg X - 1

№ no/no	Year	W	σ	B	σ	V	σ	R	σ	n
1	1986	9.384	0.009	9.678	0.006	8.854	0.004	7.956	0.002	484
2	1987	9.373	0.008	9.663	0.007	8.849	0.005	7.941	0.007	270
3	1988	9.362	0.003	9.659	0.002	8.844	0.008	7.938	0.006	604
4	1989	9.354	0.006	9.651	0.003	8.840	0.008	7.935	0.002	358
5	1990	9.341	0.004	9.642	0.003	8.837	0.007	7.930	0.002	143
6	1991	9.330	0.006	9.635	0.004	8.833	0.002	7.928	0.008	158
7	1992	9.321	0.006	9.628	0.003	8.831	0.003	7.926	0.006	168
8	1993	9.308	0.009	9.623	0.008	8.830	0.006	7.924	0.003	186
9	1994	9.298	0.008	9.621	0.006	8.829	0.003	7.922	0.002	195
10	1995	9.290	0.012	9.619	0.008	8.827	0.006	7.920	0.004	208
11	1996	9.292	0.004	9.623	0.002	8.832	0.007	7.921	0.006	216
12	1997	9.296	0.008	9.627	0.006	8.836	0.005	7.923	0.004	218
13	1998	9.301	0.007	9.635	0.004	8.840	0.005	7.925	0.004	228
14	1999	9.317	0.010	9.641	0.006	8.843	0.005	7.929	0.004	241

It is nesessary to note that the mean points for separate nights of observations near orbital phases $\varphi = 0.0$ and $\varphi = 0.5$ sometimes deviate from the light curve of the system. This fact can probably be explained by small mutual partial eclipses of the optical component of CBS and non-stationary accretion structure (AD and, probably, the gas crown of the system), localized in the close vicinity of the invisible relativistic companion.

6 QUALITATIVE ANALYSIS OF THE OPTICAL AND X-RAY DATA FOR THE CLOSE SYSTEM

Qualitative analysis of the optical and X-ray data for the system for the period from 1986 until 1993 (author's data) and from 1994 until 2005 (published data from other authors) was carried out (See Fig.6).

Specialized X-ray observatories EXOSAT, RXTE/ASM, RXTE/PCA, BATSE and others gave extensive data on X-ray emission of Cyg X-1 for analysis and comparison with the optical data.

While averaging the points of optical observations for the period 1995 – 1996 (peak of active state of the system) and up to 2005 and comparing them to the X-ray data obtained by RXTE/ASM at the same period, we can note the increase of X-ray activity of the system with simultaneous

decrease of the mean optical brightness.

Such behaviour of the system can be explained in the frameworks of the selected gas-dynamical model: some change (in this case increase) of accretion rate with simultaneous increase of the radius of the optical component of the system (in the frameworks of Roche model – the change of degree of filling by optical star of its Roche lobe). The temperature of supergiant decteases by some value.

To reveal the degree of correlation between optical and X-ray radiation it is nesessary to take into consideration the existing connection from the frequency analysis: in the optical and X-ray light curves the orbital components with significant amplitudes are present. The amplitude in the X-ray component of the spectra is about $0^m.16$, and in the optical band – $0^m.045$ (Belloni, Mendez et al., 1996). Analysis of fast variability and functional dependence between optical and X-ray bands revealed very low dependence at the level of a few percent, while comparison of long-term changes in these bands gives significant correlation of $42 - 45\%$ [14]; [15].

The correlation coefficients should be small because of the changes of mean phase light curves of the system: double wave with equal minima in the optics and single wave with narrow secondary minimum in X-rays [14].

7 REALISTIC MODEL OF SMALL AMPLITUDE LONG TERM OUTBURST

Dynamo model to account for the behaviour of the peculair object V1357 Cyg in the close binary system V1357=Cyg X-1.

It is generally assumed that the physical nature of the solar cycle is related to the action of a dynamo mechanism in the depths of the solar convection zone.

По видимому, такой же механизм динамо действует и в глубокой, но тонкой конвективной зоне сверхгиганта, каковым является оптический компонент в ТДС V1357 Cyg= Cyg X-1.

This mechanism operates due to the combined effect of differential rotation and the so-called $\alpha - effect$, which is related to convection breaking the mirror symmetry in the rotating body.

This mechanism is probably also responsible for the evolution of the magnetic field in other celestial bodies, including the Earth, stars and galaxies [34].

The dynamo effect is a process by which a magnetic field is generated by the flow of an electrically conducting fluid. It is believed to be responsible for magnetic fields of planets, stars and galaxies [27]. Fluid dynamos have been observed in laboratory experiments in Karlsruhe [28] and Riga [29]. More recently, the VKS experiment displayed self-generation in a less constrained geometry, i.e., a von Karman swirling flow generated between two counter-rotating disks in a cylinder [30], [31].

We suppose that the described above event of slow outburst: the increase of brightness starting at about 1986 with probable maximum in the period 1994-1995 and further decline to the usual

level at 2000, should be considered as the process of stellar activity of the normal star (supergiant) in the double system.

We suggest that the physical nature of this event is to some extent similar to the solar cycle, that is somehow connected to changes of the large-scale magnetic field of the supergiant. This proposal is based on the fact that the temporal and energetical characteristics of the slow outburst differ significantly from such parameters as the time of X-ray outbursts (milliseconds), connected with the accretion of matter on the black hole, or from the period of the orbital variability ($5^d.6$).

Let us consider the known processes leading to formation and evolution of magnetic field on normal stars. There might be some variant of stellar dynamo acting in the convective envelope of the supergiant.

According to modern ideas the supergiants really possess such convective envelopes, with size about of the radius of the star.

The radius of the primary is taken as $r_\star = 1.58 \times 10^{12} cm$ ([54]).

What is known about convection, are there some ideas about the degree of differentiality of the rotation?

Let us consider the action of stellar dynamo in the spherical envelope in the framework of a simpified model. The differential rotation acts on the poloidal magnetic field and creates toroidal magnetic field. From other side, the global rotation of the star leads to mirror asymmetry of convection, which allows to create poloidal magnetic field from toroidal field (so called alpha-effect) and to close the chain of self-excitation of magnetic field. This scheme was proposed by Parker in 1955 and is called Parker dynamo.

We will try to estimate the effectiveness of Parker's dynamo in supergiants on the basis of known facts about convection in supergiants.

It is well known that Parker's dynamo may excite the waves of large-scale quasistationary magnetic field in the spherical envelope (so called dynamo waves) running from medium latitudes to the equator, or, if the sign of alpha-effect is opposite, from medium latitudes to the pole. These waves are usually close to harmonical, because toroidal magnetic field changes proportionally to $\sin(t/t_c)$, where t_c is the cycle period.

At present we do not have direct evidence that the observed slow outburst is a periodical (or nearly periodical) event, but this proposal seems plausible. In this case it turns out that the photoelectic sygnal, showing the slow outburst of the supergiant in the system Cyg X-1, is different from harmonical.

For quantitative characterisation of this difference we introduce the duty cycle $Q = T_-/T_+$, where T_- is the time in low state, and T_+ is the time in high state. Taking $T_+ = 14$ years (from 1986 until 2000) and $T_- = 27$ years (from 1970 until 1986 and from 2000 until 2011) we obtain $Q = 1.9$. Assuming that for sinusoidal sygnal the moment of transition from low state to high state is at $\sin(t/t_c) = 0.5$ we get $Q = 0.5$.

So, the possibility of interpretation of the observations discussed above depends on the possibility for Parker's dynamo to produce periodically changing magnetic fields with high duty cycle. Moss et al. [32] noted that with definite set of directing parameters Parker's dynamo really

produces periodically changing magnetic field differing from sinusoidal. They proposed to search the stars with such behaviour of magnetic field among magnetically active stars, but they did not characterise its behaviour by duty cycle.

Periodically changing magnetic fields with high duty cycle, so called dynamo-splashes, were discovered experimentally while studying dynamo in the laboratory experiment VKS in Lyon, France.

Previous simulations, using the mean flow (time averaged) of the VKS experiment or an analytical velocity field with the same geometry, predicted an equatorial dipole: [45], [46], [47], [48] in contradiction with the axial dipole observed in the experiment [31].

As at present it is technically impossible to reproduce Parker's dynamo in the laboratory and the self-excitation of magnetic field in VKS experiment differs significantly from the stellar dynamo, we give below a model for dynamo-splashes. We propose it as a model for the occurrence of a slow outburst on the supergiant in the system Cyg X-1 in the form, more adequate to Parker's dynamo. At the same time we note that this model is close to the one suggested by Fove:

Reference for VKS [49], [50], [32]

It seems likely that the excited magnetic field is, in some sense, simply organized and can be described using relatively few parameters. Therefore, a qualitative description can be achieved by replacing the dynamo equations with an appropriately chosen dynamical system of a moderately high order.

Our knowledge on the distribution of sources of magnetic field generation (differential rotation and spirality) is limited, that is why we simpify stellar dynamo equations to the corresponding level. Following Parker (1955) [33] we consider this field to be axis-symmetrical and will average it over the radial size of the convective zone.

This problem was first formulated in [43] (see also [44]), where the following dynamical system was suggested:

Then we will decompose the magnetic field to Fourier series on the remaining variable (latitude) and will conserve minimal number of Fourier modes, sufficient for the model to reproduce growing magnetic field with non-vanishing magnetic moment. We also suppose that growing and oscillating magnetic field is stabilized by the simple mechanism for suppression of alpha-effect.

Then we obtain the following dynamic system (Nefedov and Sokolov, 2010 [34]):

Basic MHD equations and the description of variables:

$$\frac{dA}{dt} = -A + \sigma^{\cdot} DB - CB, \tag{1}$$

$$\frac{dB}{dt} = -\sigma^{\cdot} B + \sigma^{\cdot} A, \tag{2}$$

$$\frac{dC}{dt} = -\upsilon C + AB, \tag{3}$$

Here, A corresponds to the toroidal component of the magnetic potential and, to the poloidal magnetic field, B to the toroidal component of the magnetic field, D to the dynamo number, and C to the $\alpha - effect$. The physical meaning of the coefficient σ required addition clarification.

This system can reproduce dynamo-splashes within definite interval of the parameters.

8 Suggested model for the explanation of the slow and small-amplitude outburst in the photospere of supergiant. Proposed by A.N.Sazonov

For the interpretation of the slow and small-amplitude outburst in the photosphere of supergiant V1357 Cyg it is necessary to put forward the following realistic physical suggestions:

1. Priming magnetic field is necessary for the action of dynamo mechanism, this field should be further intensified and rebuild.

2. Close binary systems are fast-rotating stars, which should generate strong magnetic dynamo. We should expect that processes of reconnection are taking place, which are initiated by rotation stress [35].

3. If an accretion disk is present is the system, it possesses its own gas corona, which may be the source of disk (impulse) outbursts.

4. The outbursts of different duration and amplitude in double stellar systems are not analogous to the solar flares; it is necessary to take into account the presence of strong stellar coronas, which can serve as dominating mechanism for energy storing [36].

5. Stellar outbursts are much more powerful than the solar flares, perhaps because they take place on stars with stronger magnetic dynamo.

6. Sufficiently fast rotation, combied with deep convective zone may be present at supergiants similar to V1357 Cyg and increases the dynamo activity on these stars.

7. Another remarkable feature of these close binary systems, stellar microquasars, is the presence of jets and accretion disks around relativistic objects.

8. The separation then corresponds to $a = 2.28 r_* = 3.60 \times 10^{12}$ cm, and the orbital velocities are 3.13×10^7 and $1.56 \times 10^7 cms^{-1}$ for the black hole and the primary, respectively. We hereafter use a as the unit, as it gives a measure of the asymmetry in the photon paths during the orbital motion. The distance is assumed to be $D = 2$ kpc [55].

8.1 Interpretation of the outburst

All the assumptions we made give realistic basis for the interpretation of long-term small-amplitude outburst, discovered from photometric data by A.N.Sazonov

Thus, we conclude that our dynamical system can reproduce the phenomenon of cyclic activity, including at least some chaotic elements of this regime.

9 CONCLUSIONS

1. The light curve of the system for the period 1986 – 1992 is in good accordance within the errors to the mean light curves of the other authors with their sets of observations. In this work homogeneous and high-precision set of observations in the W, B, V, R filters is presented, which makes them unique and valuable for obtaining additional information of the physical proprties of the system. They allow to carry out analysis of fine effects and derive information on other physical parameters of the unique system.

2. Brighness decreases of $0^m.035 - 0^m.045$ are observed, which is equal to the contribution of accretion disc to the total luminosity of the system.

3. 10 years of photoelectical observations of the object reveal annual increase, followed by the decrease of the mean brightness of the system ("slow outburst"). The decline of brightness after the maximum in 1994 – 1996 was equal to 7% in W band, 4% in B, in the bands V and R it was nearly 2%.

4. In general, we conclude that the constructed dynamical system can qualitatively reproduce the temporal behavior of real dynamo systems of various celestial bodies.

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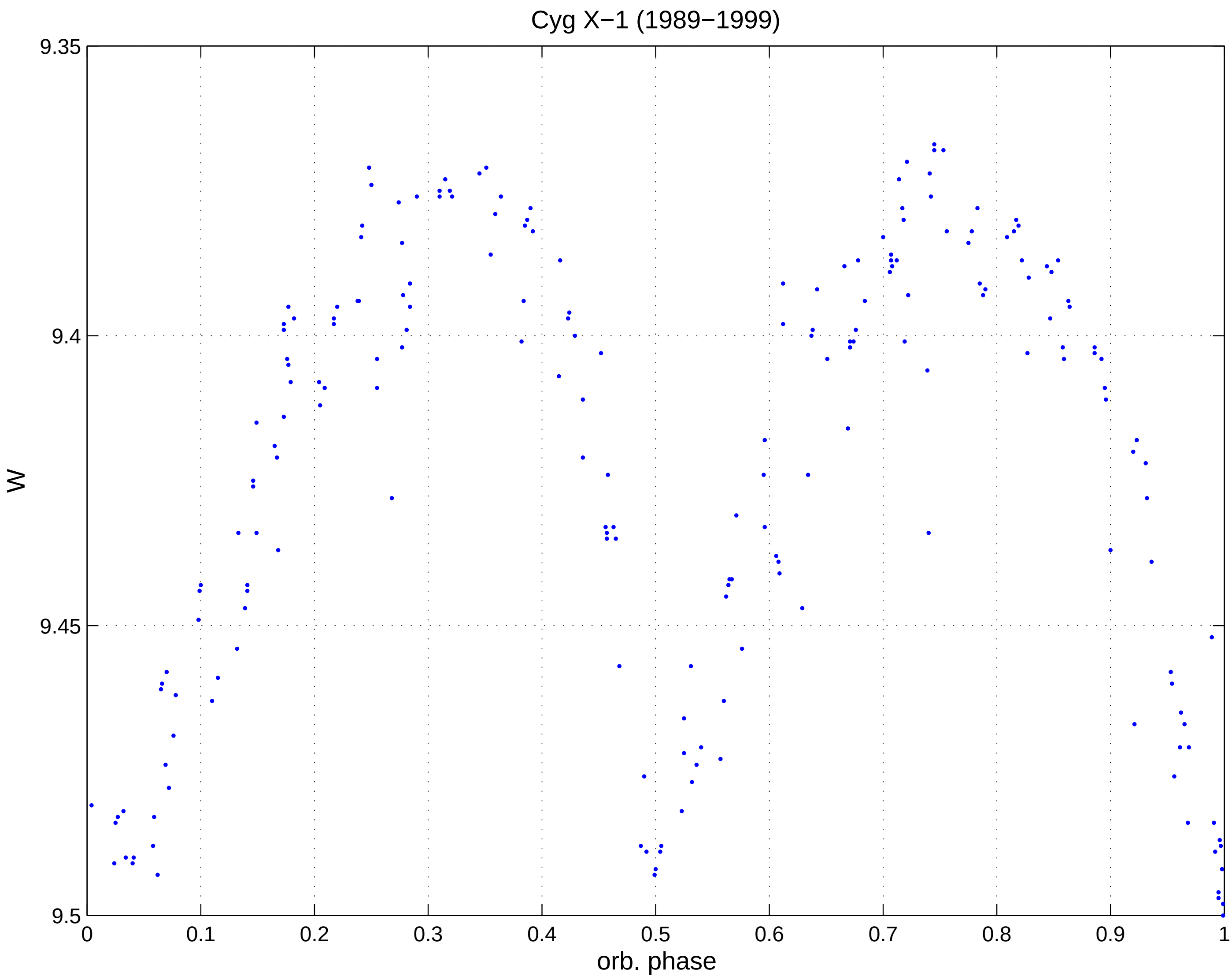


Рис. 1: W,vs. orbital phase φ for the 1989-1999 season.

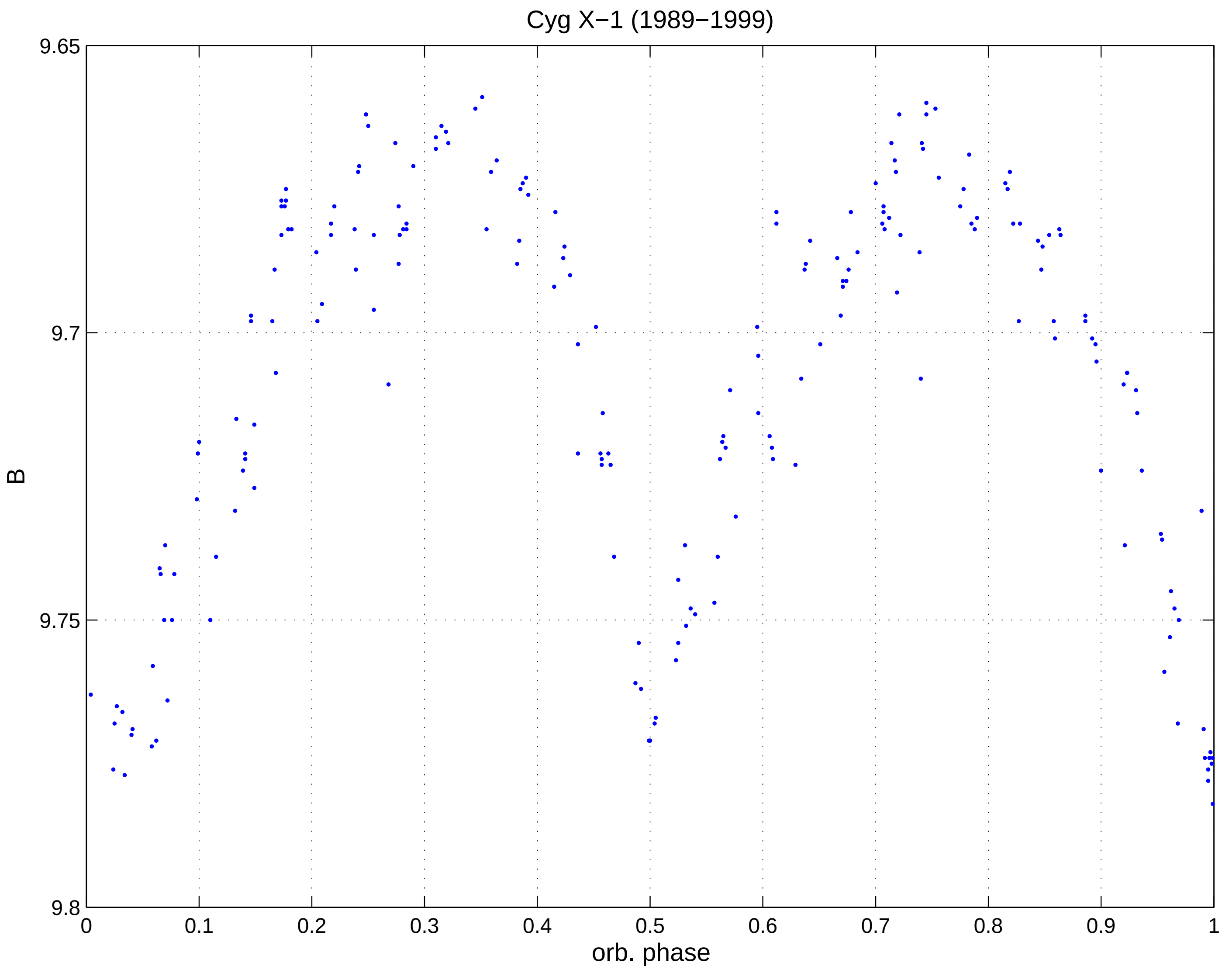


Рис. 2: B,vs. orbital phase φ for the 1989-1999 season.

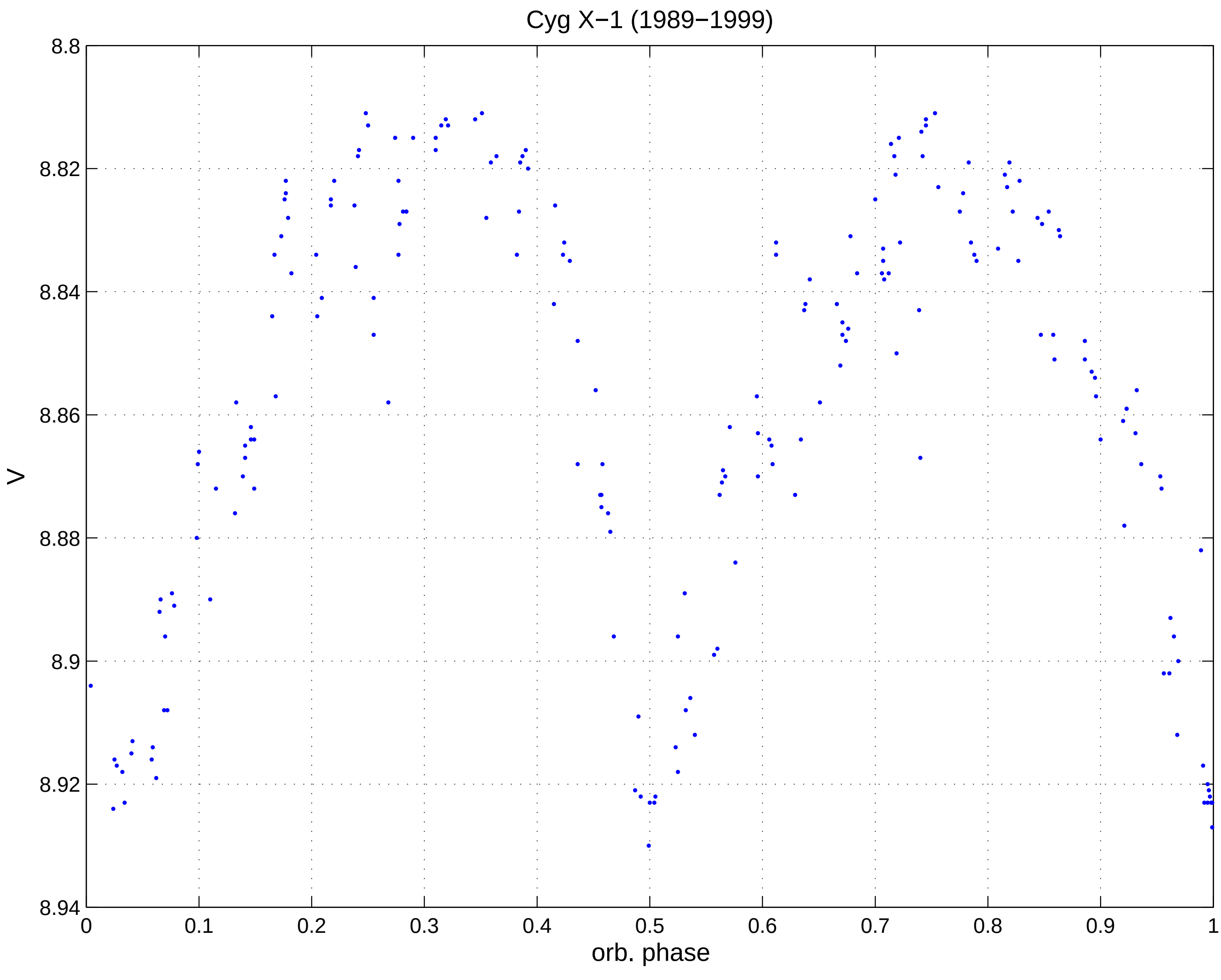


Рис. 3: V,vs. orbital phase φ for the 1989-1999 season.

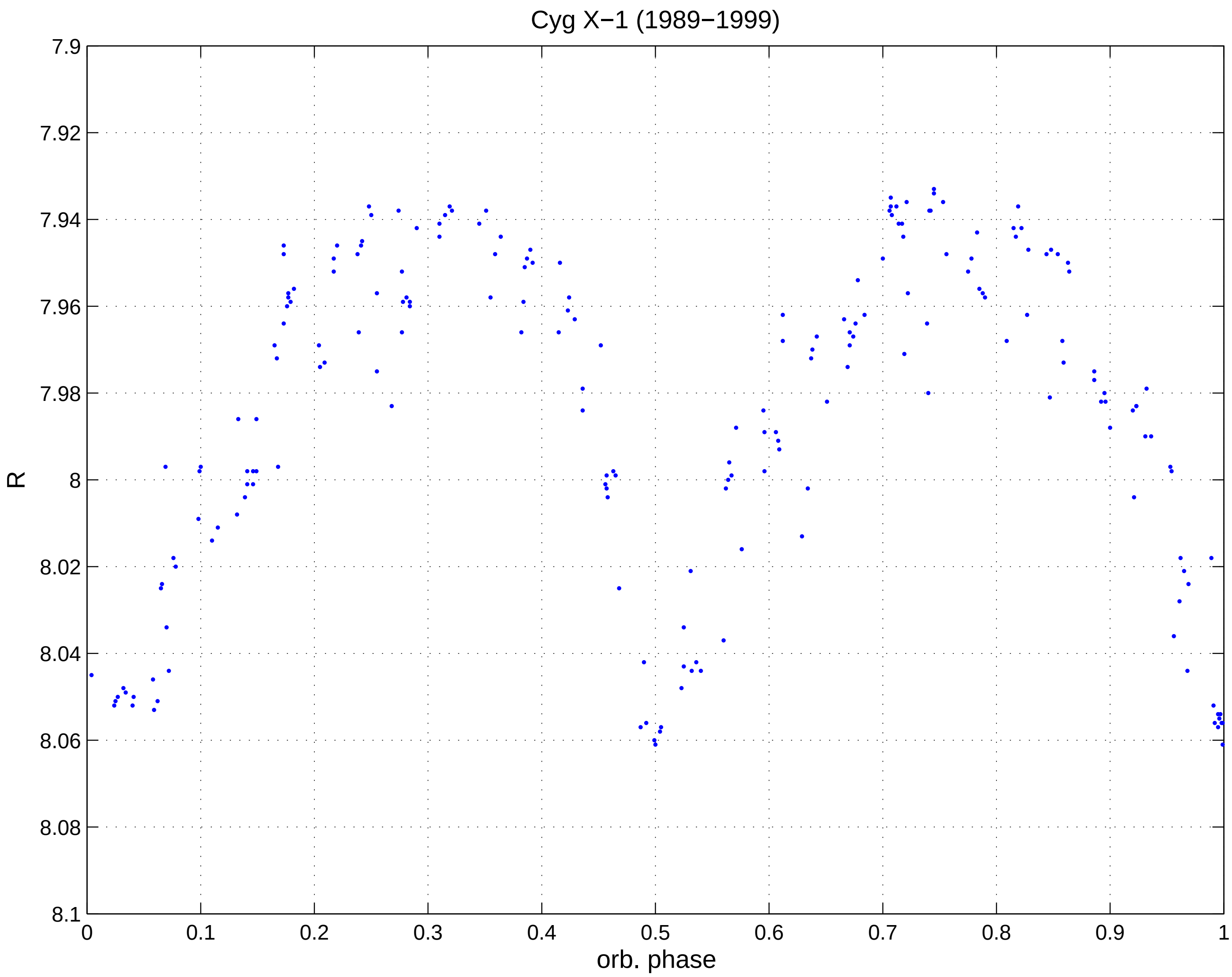


Рис. 4: R,vs. orbital phase φ for the 1989-1999 season.

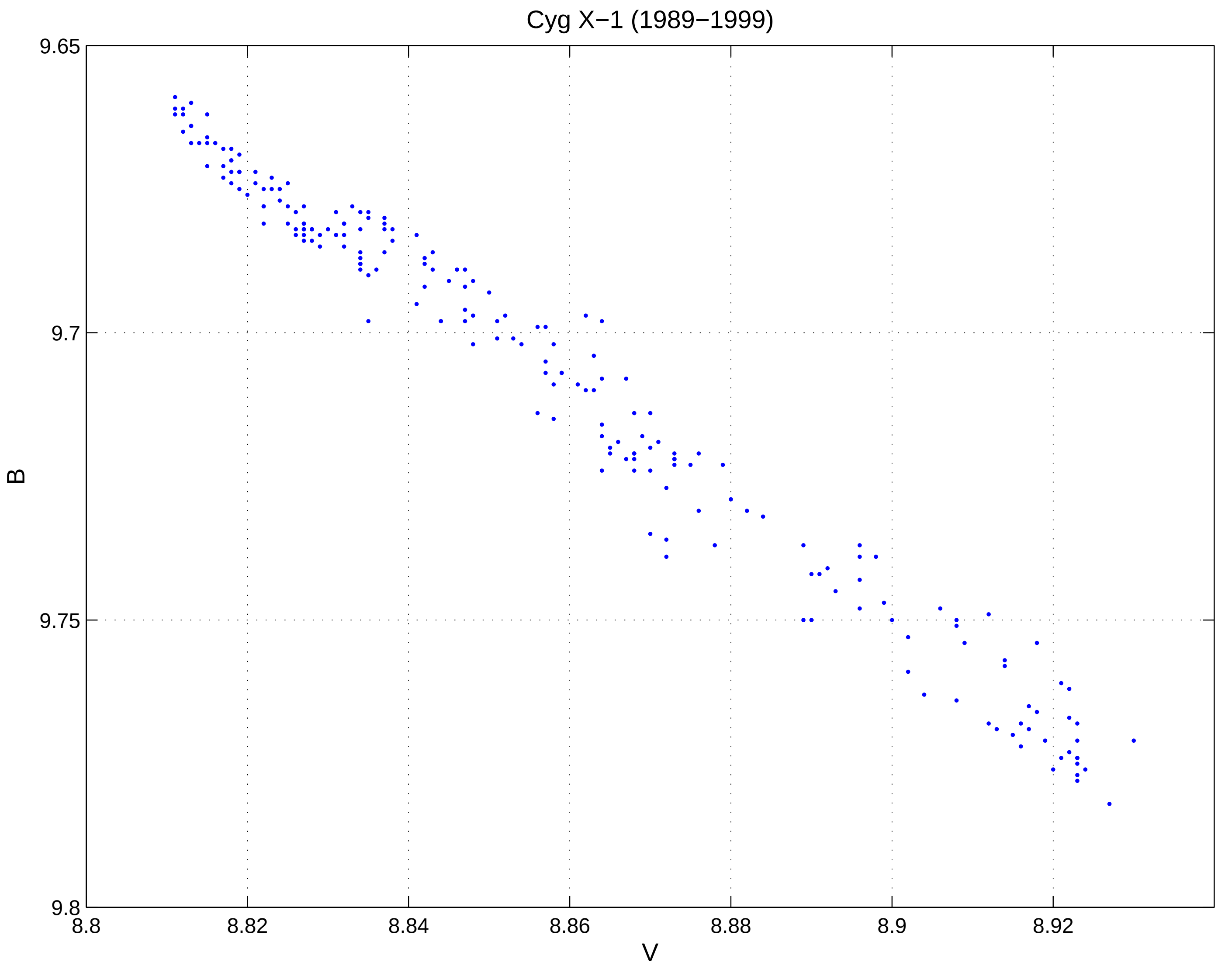


Рис. 5: B from V, vs. orbital phase φ for the 1989-1999 season.

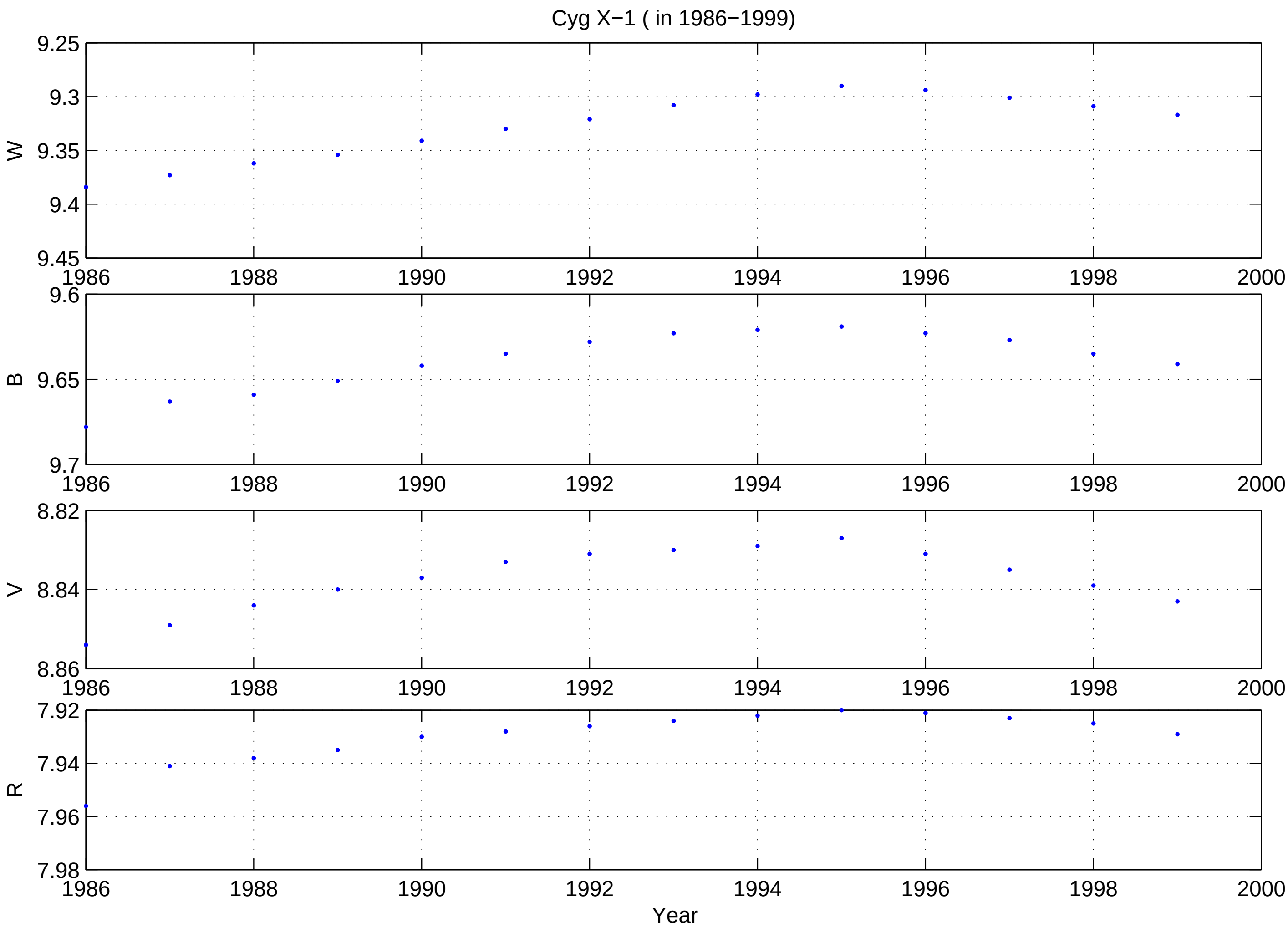
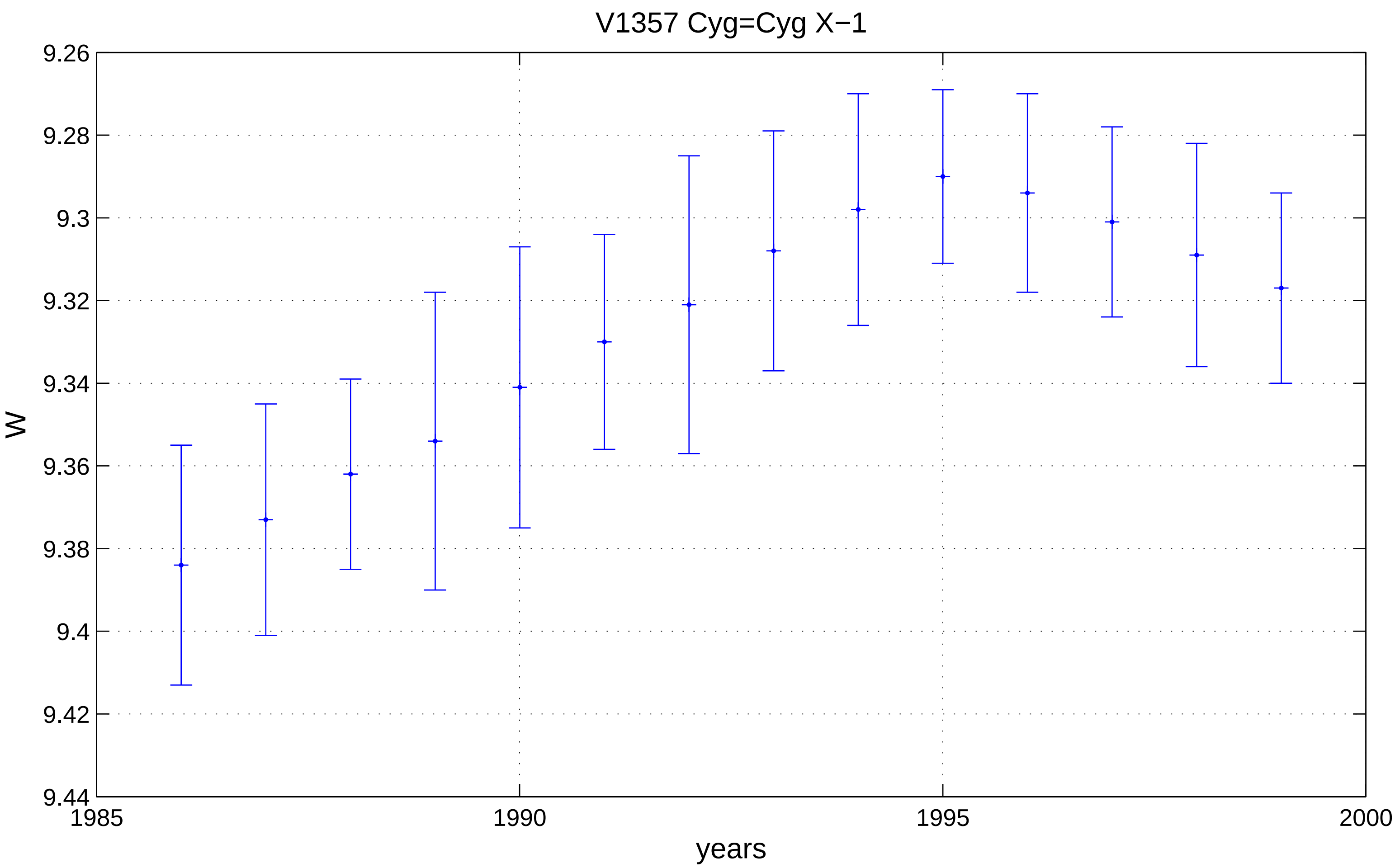


Рис. 6: $WBVR$,vs. orbital phase φ for the 1986-2000 season.



V1357 Cyg=Cyg X−1
9.26
9.28
9.3
9.32
9.34
9.36
9.38
9.4
9.42
9.44
W
1985
1990
1995
2000
years